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Abstract: PURPOSE This retrospective study evaluates the location of the arteries in the maxillary sinus, particularly in the middle portion, using cone beam computed tomography (CBCT) scans that can detect the lateral arteries with high reliability. METHODS In this retrospective study, 2 experienced independent examiners evaluated 602 sinuses on CBCT scans. DISCUSSION No significant correlation was found between the location of arteries and the patient's age, sex, or dentition. In 92.0% (P 0.001) of the sinuses, at least 1 arterial branch was detectable. CONCLUSION Based on the CBCT scans, we found that a very high proportion of patients have the maxillary artery in their lateral sinus wall, which is important information for sinus augmentation or sinus surgery.

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Cone Beam Computed Tomography Evaluation of the Artery in the Lateral Wall of the Maxillary Sinus: Retrospective Analysis of 602 Sinuses

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Purpose: *This retrospective study evaluates the location of the arteries in the maxillary sinus, particularly in the middle portion, using cone beam computed tomography (CBCT) scans that can detect the lateral arteries with high reliability.*

Methods: *In this retrospective study, 2 experienced independent examiners evaluated 602 sinuses on CBCT scans.*

Discussion: *No significant correlation was found between the location of arteries and the patient's age, sex, or dentition. In 92.0% ($P \leq 0.001$) of the sinuses, at least 1 arterial branch was detectable.*

Conclusion: *Based on the CBCT scans, we found that a very high proportion of patients have the maxillary artery in their lateral sinus wall, which is important information for sinus augmentation or sinus surgery. (Implant Dent 2018;27:434–438)*

Key Words: cone beam computed tomography, posterior superior alveolar artery, infraorbital artery, implantation

Accurate knowledge of the patient's anatomy before a surgical procedure such as implantation is important. Laceration of nerve canals or vessels during surgery can lead to prolonged suffering time and severe complications. Owing to the anatomical variations in the maxillary sinus, prior 3-dimensional (3D) imaging is often recommended before a maxillary sinus surgery.

High-resolution multidetector computed tomography (MDCT) is considered the gold standard for diagnosing sinus problems because it scans through multiple sections of the sinus at different planes and allows both bone and soft tissue to be visualized. Recently, cone beam CT (CBCT) has been introduced for dental and maxillofacial imaging.[1] Three-dimensional imaging is especially useful in sinus surgery because it provides important anatomical and pathological information.[2] Fan beam technology and a multidetector system are used in the conventional MDCT, whereas CBCT uses the cone beam technology, which generates voxel values from which gray levels are calculated.[3] The tube current is substantially lower in CBCT than that in the conventional MDCT (about 5 mA compared with 80–200 mA). CBCT also generates fewer x-ray photons than MDCT, thereby reducing the dose of radiation while allowing fast and accurate acquisition of volumetric images.[4,5] However, CBCT has some drawbacks. Because of the reduced number of photons, the images have more noise, and the contrast is, therefore, lower than that seen in MDCT.[5] Since the inception of CBCT, the comparison of density values from CBCT and MDCT has been controversial. Thus, CBCT is reliable and therefore frequently used to evaluate structures within the region of interest, including the maxillary sinus.[6]

The maxillary sinus is the largest of the paranasal sinuses and is involved in most dental implantation procedures. For the dental implant specialist, it is, therefore, necessary to understand its anatomy including the local blood supply and recognize anatomical landmarks around it.[7] The arterial vascularization of the maxillary sinus is via the maxillary artery, the larger terminal branch of the external carotid artery. Within the pterygopalatine fossa, the maxillary artery has many branches to the maxillary sinus. Intraosseous anastomoses between the dental branch of the posterior superior alveolar artery (PSAA) and the infraorbital artery (IOA) characterize the

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vascularization of the anterolateral wall of the maxillary sinus.[8] The intraosseous branch of the PSAA within the lateral sinus wall has a U-shaped course,[9] forming a concave arch with the closest point to the osseous crest, which is located near the last molar.[10]

The branches of the maxillary artery should be considered during surgical procedures through the lateral wall, such as for lateral sinus elevation, Le Fort I osteotomy, and osteosynthesis of maxillary fractures.[11] The diameter of the artery is relatively large (Fig. 1), and surgical manipulation around this artery can lead to hemorrhage, which is not necessarily life threatening but can cause complications, as it can obscure the surgeon's field of vision and damage the vascular supply of the lateral wall.[12] Accidental damage to the PSAA and its anastomoses is reported in up to 20% of dental surgeries leading to minor and major hemorrhagic complications.[13] In anatomical studies, the intraosseous PSAA anastomosis has consistently been identified in every maxillary sinus.[9,14–16] However, MDCT scans have failed to identify these structures in many patients, and so their use for this purpose has been discouraged.[13,17] Conversely, CBCT scans detect the PSAA more frequently than MDCT scans. Because the MDCT scans reveal thicker arteries than the CBCT scans,[18] it seems that the lower radiological detection of PSAA, which is present in 100% of the specimens, could be related to its small diameter.[16]

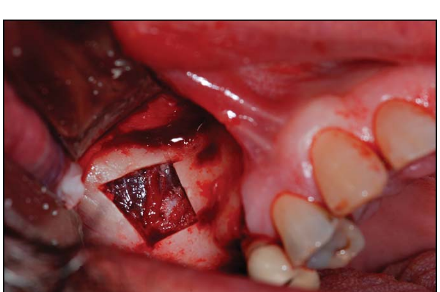

Fig. 1. Clinical photograph of a branch of the PSAA beginning caudal distal to cranial proximal. More anteriorly the artery perforated the bone, unfortunately not visible on the photograph.

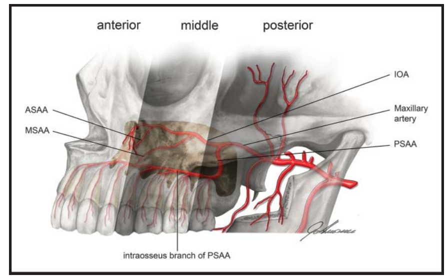

Fig. 2. Arteries of the maxillary sinus. ASAA, MSAA, postsuperior alveolar artery (PSAA), IOA. Drawn by Ruth Gottmann. ASAA, anterior superior alveolar artery; MSAA, middle superior alveolar artery.

The aim of this retrospective study was to evaluate the location of the PSAA, particularly in the middle portion, which is of utmost importance when preparing for a dental implant surgery, using CBCT scans.

Material and Methods

A total of 301 high-quality CBCT scans were retrospectively selected and analyzed. The key inclusion criterion was the presence of a complete midface without artifacts, movements, or pathologies in the maxilla on both sides. The patients were 18 years of age or older. All the CBCT scans were performed using KaVo 3D eXam (KaVo, Biberach, Germany). This scanner uses a silicon flat-panel detector (20 × 25 cm). The voxel size was set to 0.125, 0.25, 0.3, or 0.4 mm. The scan was set at a constant high-frequency potential of 120 kV (peak), and the occlusal plane for each patient was set parallel to the floor using a chin rest. The scans were evaluated on an NEC Display Solutions MultiSync MD301C4 high-resolution screen.

The scans were analyzed by a suitably experienced dentist and an oral and maxillofacial surgeon. Both sides were analyzed, and each side was evaluated as 1 sinus, resulting in 602 analyzed sinuses. On the sagittal layer, the sinus was divided into 3 parts: the anterior part, ranging from the anterior point of the sinus until distal to the first (maxillary) premolar; the middle part, extending

Fig. 3. Shows the anterior superior alveolar artery and the ending of the IOA on an aligned sagittal layer and was counted as visible in the anterior part.

Fig. 4. Shows the distal intraosseous part of the PSAA in the same patient and counted as visible in the distal part.

from the anterior part of the second premolar to the distal part of the second molar; and the posterior third, extending from the second molar to the maxillary tuberosity (Fig. 2). Within these areas, the visibility of the artery was determined and evaluated based on the number of arteries seen. A CBCT scan of an aligned sagittal layer shows the ASSA and the ending of the IOA (Fig. 3), whereas Figure 4 shows the distal intraosseous part of the PSAA in the same patient.

Furthermore, age, sex, and the completeness of dentition in the upper jaw were noted. The completeness of the dentition was recorded as full dental status, partial dental status, or edentulous.

All the statistical analyses were performed using IBM SPSS Statistics for Windows (version 21.0; IBM Corp, Armonk, NY). The Wilcoxon signed-rank test and Pearson product–moment correlation were calculated to determine any correlations between age, sex, artery location, and the completeness of dentition. The interclass correlation and P values were evaluated. A P value $<$ 0.05 was considered statistically significant.

Table 1. Expecting a Difference of Artery Visibility in CBCT Scans Between Age Groups Because of Bone and Artery Calcification Could Not be Demonstrated in This Study

	Anterior	Middle	Posterior
Overall in percent			
None	18.3	16.1	8.0
1 art	58.3	39.2	30.4
2 art	21.7	37.1	46.6
3 art	1.7	7.6	15.0
Under 30 y in percent			
None	18.8	17.9	8.5
1 art	61.2	45.9	31.2
2 art	19.1	30.4	47.8
3 art	0.9	5.8	12.5
30–60 y in percent			
None	19.1	17.4	7.3
1 art	55.7	32.2	28.7
2 art	23.5	42.6	48.3
3 art	1.7	7.8	15.7
Over 61 y in percent			
None	16.2	11.5	8.1
1 art	58.1	39.9	31.8
2 art	23	38.5	42.6
3 art	2.7	10.1	17.5

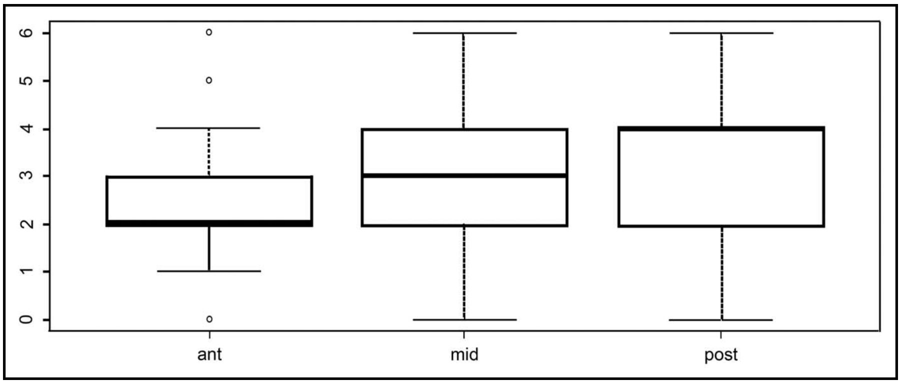

Fig. 5. Pairwise Wilcoxon signed-rank test shows better visibility of the artery in the posterior part compared with the mid and anterior part ($P > 0.001$). In the posterior part, the artery has a wider caliber, which simplifies detection by CBCT scans.

Results

A total of 602 sinuses (324 women, 278 men) met the inclusion criteria. The voxel size was set to 0.4, 0.3, 0.25, and 0.125 mm for 528, 68, 4, and 2 CBCT scans, respectively. The average age of the patients was 44.16 years [range: 18–97], and the median age was 43 years. Although 224 sinuses were from patients younger than 30 years, 230 were from patients aged between 31 and 60 years, and 148 were from patients older than 61 years.

At least 1 artery was seen in the posterior, middle, and anterior parts in 554 (92.0%), 505 (83.9%), and 491 (81.7%) of the sinuses, respectively (Table 1). A pairwise Wilcoxon signed-rank test confirmed a significantly higher artery count in the posterior part than in the middle part ($P < 0.001$) and a higher artery count in the middle part than in the anterior part ($P < 0.001$) (Fig. 5).

There was no correlation between the visibility of the arteries and the patient's sex and age or with the 3 dentition types (full dentition, partial dentition, or edentulous). There was no statistical difference between the findings of the 2 examiners. The intraclass correlation was 0.915.

Discussion

The current data show that 505 (83.9%) of the sinuses had at least 1 visible branch of the PSAA in the middle part of the maxillary sinus. This finding is consistent with the CBCT meta-analysis of Varela et al, which showed a 78.1% (95% CI 61.3–95.0) detection rate of the artery in the middle portion of the maxillary sinus.[18] In 1 study, the anastomoses of the PSAA were detected in 67.1% of the CBCT scans,[19] whereas in another, it was detected in 51.9% (95% CI 42.3–60.1) of the MDCT scans. In cadaveric studies, anastomoses between the PSAA and the IOA were detected in 100% of cases.[9,14–16] The discrepancy in the detection rates of the artery between the CBCT and MDCT scans does not imply its absence but merely that it is not visible with the current technique.

The current data showed no statistical correlation between sex and the visibility of the artery ($P = 0.53$). These findings are in contrast with those of Varela-Centelles et al,[20] who concluded that arteries are likely to be larger and more visible in men. Kim et al[21] found a higher prevalence of the PSAA on MDCT images in men (64%) than in women (40%).

Our data did not show any correlation between age and detection rates in CBCT ($P = 0.26$). These findings are consistent with those of Kim et al,[21] and the participants' ages in their study were limited to 45 to 65 years. In the current study, we evaluated subjects aged between 18 and 97 years and found that the detection rate does not vary with age. The patients aged 18 to 30 years (224 sinus) showed at least 1 artery in 190 (85.0%) of scans compared with 196 (85.4%) of scans of participants aged 31 to 60 years (230 sinus) and 130 (88.1%) among the group older than 60 years (148 sinus). The statistical analysis showed a tendency but no significance. To the best of our knowledge, this has not been previously reported. The different voxel sizes of the CBCT scans did not influence the visibility of the artery. Further studies should be performed with the latest, most modern CBCT and MDCT scanners to clarify the possible correlation between the imaging visibility and age.

Knowledge of the exact course and diameter of the artery in the maxillary sinus is important for preoperative planning. Knowing the artery's location with 100% certainty from anatomical studies[16] must be taken into consideration when planning a lateral sinus surgery. The best possible imaging should be performed in advance to reduce the risk of severe bleeding by laceration of the lateral artery.[22]

A limitation to the present study is that it is retrospective, which has the potential for bias. However, this limitation might have been countered by a large number of patients/sinuses that were evaluated in this study.

A subject for future research would be to determine the size of the PSAA that needs to be identified before surgery and the frequency at which it can be detected by CBCT. The diameter of the alveolar antral artery shows wide variation.[23] The risk of perioperative bleeding for alveolar antral arteries with diameters between 1 and 2 mm is about 57% when the sinus floor is elevated,[20] which further increases for diameters more than 2 mm.

Conclusion

We concluded that the cone beam computed tomography (CBCT) scanner has a high probability of detecting arteries in the lateral wall of the maxillary sinus. These findings allow adequate preoperative planning in sinus surgery or sinus augmentation.

Approval

The study was approved by the cantonal ethics committee Zurich, Switzerland KEK-ZH-Nr. 2015-0220 and fulfills the Declaration of Helsinki on medical research protocols and ethics.

Disclosure

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

Roles/Contributions by Authors

C. Rostetter and A. Hungerbühler: Data collection and writing. Data collection and writing. M. Blumer: Statistics and Interpretation. M. Rücker: Proof reading and Conception. M. Wagner: Statistics and Interpretation. B. Stadlinger: Ethic votum and Proof reading. H.-T. Lübbers: Conception and writing.

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